DOCUMENT RESUME

ED 029 474 EF 003 233

Good Practice Recommendations in the Field of Heating, Ventilation, and Air Conditioning for Health Related Research Laboratories.

Public Health Service (DHEW), Washington, D.C.

Pub Date May 66

Note-21p.

Available from-Office of Architecture and Engineering, Div. of Research Facilities and Resources, National Institute of Health, Bethesda, Maryland 20014

Journal Cit-Laboratory Design Notes; May 1966

EDRS Price MF-$0.25 HC-$1.15

Desc iptors-Air Conditioning, *Controlled Environment, Criteria, *Facility Guidelines, Health Facilities, Heating, *Laboratories, Mechanical Equipment, Refrigeration Mechanics, *Research, Safety, Temperature, *Ventilation

A collection of laboratory design notes to set forth minimum criteria required in the design of basic medical research laboratory buildings. Recommendations contained are primarily concerned with features of design which affect quality of performance and future flexibility of facility systems. Subjects of economy and safety are discussed where appropriate. Contents include--(1) general definitions, (2) air conditioning, (3) ventilation requirements, (4) ventilation quantities, (5) room loads, (6) central unit loads, (7) central air handling units, (8) air distribution, (9) refrigeration, (10) temperature and humidity control, and (11) cost estimates. (RH)

Laboratory Design Notes

Distributed in the interest of improved research laboratory design

GOOD PRACTICE RECOMMENDATIONS

IN THE FIELD OF

HEATING, VENTILATION, AND AIR CONDITIONING

FOR

HEALTH RELATED RESEARCH LABORATORIES

U.S. Department of Health, Education, and Welfare – Public Health Service

PREFACE

The purpose of these Laboratory Design Notes is to set forth the minimum criteria which are required in the design of basic medical research laboratory buildings. The professional's experience in the systems design for modern multi-story buildings is assumed. The recommendations set forth herein are primarily concerned with features of design which affect quality of performance and future flexibility of facility systems. However, subjects of economy and safety will be discussed where appropriate.

Ventilating and air conditioning systems shall conform to the requirements of NFPA Standard No. 90A, "Air Conditioning Systems Other Than Residence Type," with the exception of any systems which handle flammable or explosive material. These shall conform to NFPA Standard No. 91, "Blower and Exhaust Systems." Ventilating and air conditioning systems for hospital operating rooms must conform to the requirements of Bulletin No. 56 of the National Fire Protection Association, except as modified herein.

May 15, 1966

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HEATING, VENTILATING, AND AIR CONDITIONING

I. GENERAL

A. Definitions

1. Air Conditioning

The term implies control of any or all of the physical and chemical qualities of the air. Air conditioning is defined as the simultaneous control of the air's temperature, humidity, cleanliness, and distribution to meet the requirements of the conditioned space.

2. Ventilation rate

The rate at which outside air is to be mechanically supplied to the space expressed in units of "numbers of air changes per hour."

3. Categories of Research Facilities

Class A - Laboratories with 100 percent flexibility for conversion from one program to another. They would be primarily intended for research in the basic scientific disciplines of biology, chemistry, and some aspects of the physical sciences. They are to be utilized where there is possibility of interference with the research work in other locations of the building. Class A laboratories are also needed where toxic chemical or infectious biological work in the present or future programs is a possibility. This type of facility will be more costly for the heating, ventilating, and air conditioning systems than Class B laboratories.

Class B - Laboratories with less built-in flexibility of systems, primarily intended for use of those disciplines not involving the basic sciences of biology and chemistry or the hazardous aspects of physical sciences. Their use would be largely for the social sciences, psychiatry, public health work, or epidemiology. Mechanical systems for such space would be designed for a narrower range of research activities and would not be expected to be capable of conversion to disciplines intended for Class A space without considerable renovation.

Class C - Most facilities in this class would not be laboratories at all, but would include such structures or space as horse barns and cattle barns that can be functional without sophisticated utilities, services, and air conditioning.

Class D - This category is reserved for special research functions such as Biotron or Betatron buildings, hyperbaric chambers, and special rooms designed for one particular function with specialized characteristics and physical requirements. Such facilities would be generally inflexible and have requirements not found in the criteria for Class A or Class B facilities.

II. AIR CONDITIONING

A. General - Air conditioning is required in all health-related spaces of a building located in a geographic area where the summer outdoor design dry bulb temperature is 80° F or higher. Also, air conditioning is essential to intensive program use of space in the block-type building with the attendant high internal heat gain.

B. Types of Systems - The following types of mechanical refrigeration systems are recommended:

1. Chilled water equipment - to achieve maximum ease and high degree of control of temperature and humidity.

2. Direct expansion equipment - if used, should be limited to the smaller systems (thirty tons or under in total capacity) and used only when (a) the selection of chilled water is an uneconomical one, and (b) the refrigerant suction mains would not be over 250 feet long.

3. Self-contained (packaged) units - through-the-window units and multizone units are not suitable for Class A systems having the requirement for the continuous supply of 100% outside air (no recirculation) on a year-round basis.

4. Central air handling units - should be of the field-assembled type for capacities in excess of 10,000 c.f.m. Factory-built units have application in existing buildings where space restrictions may prevent the use of field-assembled units.

III. VENTILATION REQUIREMENTS

A. General - Ventilate mechanically all air-conditioned spaces, fresh air being introduced at the conditioning unit. Provide mechanical or gravity ventilation in all other rooms where window or other natural ventilation is insufficient to remove heat, fumes, smoke, and odors, and provide fresh air for respiration.

B. Mechanical Supply - Install mechanical supply ventilation in the following spaces:

1. Laboratories and ancillary spaces (offices, conference rooms, etc.)
2. Animal rooms
3. Patient rooms
4. Transformer and switchboard rooms within buildings, containing equipment of 300 kva capacity or more *
5. Elevator machine rooms
6. Escalator machine rooms *
7. Corridors

* Mechanical exhaust may be substituted if conditioned air from the building or other reasonably clean make-up air supply is available. Supply or make-up air entering elevator machine rooms shall be filtered, either at the supply unit or in the make-up duct at a point near the room.

C. Mechanical Exhaust - Provide mechanical exhaust ventilation in the following spaces:

1. Kitchens
2. Toilets
3. Service closets adjoining air-conditioned spaces
4. Locker rooms
5. Garages (included within the building)
6. Autoclave and sterilizer rooms
7. Refrigerating rooms
8. Cage and glass washing rooms
9. Animal holding rooms and operating rooms
10. Laboratories and ancillary spaces
11. Solvent, acid, and gas storage rooms
12. Patient rooms

PARAGRAPH III (Continued)

D. Gravity Ventilation

1. Service closets which do not adjoin air-conditioned spaces
2. Transformer and switchboard rooms containing equipment of less than 300 kva capacity
3. Storage rooms, other than for solvent, acid, and gas storage
4. Boiler rooms

Where layout or space availability does not permit adequate gravity ventilation, provide mechanical ventilation for the foregoing spaces. Supply and/or exhaust ventilation may be used, provided the arrangement will assure that fumes, heat, and odors will not enter other spaces in the building.

E. Air Imbalance - Wherever supply or exhaust ventilation is indicated, provide additional exhaust or supply so that the imbalance will be no greater than the normal infiltration into the area. It is necessary that each Class A laboratory (and adjoining rooms), animal rooms, and patient rooms have individual supply and exhaust duct connections, as exhaust air from these spaces may not be recirculated. However, exhaust air from Class B spaces may be collected and ducted into Class A space for use as fume hood makeup air. The use of corridor partition louvers will not be permitted since they allow the passage of smoke and flames.

IV. VENTILATION QUANTITIES (NO MECHANICAL COOLING)

A. Health-related Spaces - Air quantities supplied are required to be sufficient to limit the temperature rise in the room due to internal heat gain not to exceed 10 degrees F. Requirements for the minimum number of outside air changes per hour are as follows:

	Minimum Air Changes per Hour
1. Animal rooms	12 to 15
2. Laboratories	6 to 8
3. Offices	4 to 6
4. Patient rooms	4 to 6
5. Conference rooms	6 to 8 (15 to 20 under heavy occupancy)
6. Classrooms	6 to 8
7. Auditoriums	6 to 8
8. Operating rooms	6 to 10

PARAGRAPH IV (Continued)

B. Kitchens - Requirements for the quantity of air exhausted from a kitchen are not less than 4 c.f.m. per square foot of floor area. Quantities exhausted through hoods are required to be sufficient to maintain a velocity of 60 to 75 feet per minute through the projected area.

C. Storage Rooms - Storage rooms leading outdoors may be ventilated by gravity, using grilles in the outside doors or outside walls. Top grilles shall have a total free area of one square inch per square foot of floor area, and bottom grilles should have an equal area. Rooms ventilated mechanically are required to have from 0.2 to 1.0 c.f.m. of exhaust per square foot of floor area depending upon the odors, fumes, and dust originating from the material to be stored.

D. Service Closets or Gear Rooms - Gravity ventilated closets require louvers not less than 3/4 the width of the door and substantially the full height of the door. Mechanically ventilated closets require a minimum of 50 c.f.m. of exhaust.

E. Service Rooms - Air quantities exhausted from small rooms containing steam pressure reducing valves, water heaters, condensate tanks, autoclaves, sterilizers, cage washers, and glass washers should be sufficient to limit the room temperature rise to 10^{o} F above the summer outdoor design dry bulb temperature. Where the heat load cannot be estimated accurately, provision for thirty air changes per hour is recommended. Where service spaces with high internal heat gain are adjacent to or below offices or other occupied space, insulation of the partitions or ceilings or introduction of ventilation air through a dropped ceiling in the service room is recommended to reduce heat transfer. Similarly, service enclosures containing boiler or incinerator stacks should be ventilated and/or insulated.

F. Transformer Rooms -

1. For gravity ventilation, inlet and outlet ducts and grilles should be provided with free areas of 144 square inches for the first 40 kva, or less, plus 4 square inches for each additional kva transformer capacity. Areas shall be increased 20 percent for rooms under a roof. Where arrangements permit, duplicate sets of grilles on opposite sides of the room are desirable.

2. For mechanical ventilation, the air quantities supplied should be 5 c.f.m. per kva of transformer capacity, providing the entering air temperature does not exceed 90 degrees F.; otherwise, 6 c.f.m. per kva is required. Additional air, based on a 10 degree F. room temperature rise, should be supplied if the room is under a roof.

PARAGRAPH IV (Continued)

G. Switchboard Rooms - Gravity ventilated switchboard rooms should have louvers not less than 3/4 the width of the door and substantially the full height of the door. Mechanically ventilated rooms should have not less than 10 air changes per hour. If the actual heat generation is known, particularly where motor starting equipment is located in the room, the air quantity should be based on a room temperature rise of 10 degrees F.

H. Elevator and Escalator Machine Rooms

For mechanically ventilated electric elevator machine rooms, minimum air quantities per horsepower are as follows:

Number of Machines	C.F.M. per HP
1	120
2	102
3	92
4	86
5	80
6	75
7	71
8	68
9	65
10	62

For rooms under roofs, additional air must be supplied based on a 10 degree F. room temperature rise. If makeup air is drawn from air-conditioned space, the tabulated values may be reduced, provided the room temperature will not exceed 105 degrees F. at any point. For hydraulic elevators, use 1/2 of the tabulated values. For escalator motor chambers, use 1/3 of the tabulated values.

I. Refrigerating Machine Rooms - Provide minimum quantities of exhaust air in accordance with ASA B9.1-1964 (ASHRAE Standard 15-64).

V. ROOM LOADS (COOLING)

A. Design Factors - Outside design-dry and wet bulb temperatures for calculating room loads generally should be those as taken from the ASHRAE Guide and Data Book, latest edition. It is recommended that the outdoor design temperatures be selected so that, on the average, these temperatures will not be equalled or exceeded more than one percent of the time in the case of design dry bulb and two and one-half percent of the time in the case of design wet bulb. This determination

to be made for the warmest consecutive six months as determined by the mean wet bulb temperature (May through October). If the guide does not list the required temperatures, comparable data taken from other reliable sources should be used. Indoor conditions on which loads are based should be as follows, or as specified by the particular medical research program:

Space	Temperature-Degrees F.	Relative Humidity-Percent
Laboratory	75	50
Animal room	72 - 78	40 - 50
Office	75	50
Surgical suites	70 - 80	50 - 60
Patient rooms	75	50

B. Sensible Heat - Include with the routine sensible heat load calculations the following additional factors which are desirable for health-related research facilities:

1. The lighting load used in calculations should be the actual load, or four watts per square foot of floor area, whichever is the greater.

2. The electrical load used in the calculations for class "A" laboratory space should include an additional twelve watts per square foot of floor area.

C. Latent Heat - Room latent heat must be determined for all rooms in order to establish the lowest dew point temperature required. Latent heat loads include latent heat of occupants, animals, and miscellaneous moisture releasing equipment such as hot water baths and other non-hooded evaporators.

Latent heat factors to be used for animals are as follows:

	Weight-lbs.	BTU/HR/Animal
Mouse	.0484	0.6
Hamster	.2640	2.5
Rat	.5500	4.3

	Weight - lbs.	BTU/HR/ Animal
Guinea pig	.7700	5.6
Chicken	up to 7 lbs.	30.0
Rabbit	up to 8 lbs.	34.0
Cat	up to 8 lbs.	34.0
Monkey	up to 12 lbs.	43.0
Dog	up to 60 lbs.	150.0

VI. CENTRAL UNIT LOADS (COOLING)

A. Air Quantities - Each central unit must be designed to deliver a total air quantity equal to the sum of the maximum air quantities required by the rooms served plus an allowance for duct leakage. No allowance should be made for diversity in time of maximum room loads. A diversity factor should be used, however, to determine maximum and minimum quantities of air in those cases where intermittent high heat gain and chemical fume hood makeup air requirements are handled by the same central air handling unit. The air delivered by central units should include outside air in the following minimum amounts:

1. Type "A" laboratories - 100 percent of outdoor air at all times, with a minimum of 6 to 8 air changes per hour. In order to reduce the hazards of cross contamination of experimentations or the spread of odors, toxics, and other foreign agents, no recirculation of air between laboratories is permitted.

2. Type "B" laboratories - A minimum of 4 to 6 air changes per hour with a minimum of 25 percent outdoor air. The requirement is to reduce the buildup of human odors only, in which instance recirculation between rooms usually is not considered to constitute a hazard to the medical research program.

3. Offices - A minimum of 4 to 6 air changes per hour, with a minimum of 25 percent outdoor air.

4. Animal Rooms - 100 percent outdoor air at all times, with a minimum of 12 to 15 air changes per hour.

5. Operating Suites - 100 percent outdoor air, with a

minimum of 6 to 10 air changes per hour.

6. Patient Rooms - 100 percent outdoor air, with 4 to 6 air changes per hour.

B. Recirculation of Air - Limit recirculation of building air to those central units which serve rooms and spaces other than Type "A" laboratories, operating rooms, patient rooms, or animal rooms. Indirect heat recovery devices may be found to be feasible to conserve utilities used in heating and cooling the supply air.

VII. CENTRAL AIR HANDLING UNITS

A. General

1. Outdoor Air Intakes - Where possible, locate outdoor air intakes so that air will not be drawn across wide roof areas or from street and grade areas. Use extreme care in coordinating the intake and discharge openings of a building so that intakes will receive no air from the discharge openings of ventilating systems, cooling towers, chimneys, etc., and no fumes from vehicles at loading platforms, fuel tanks, etc. In those cases where recirculated air is permitted, auxiliary intakes may be installed to provide 100 percent outdoor air for standby ventilation and reduction of refrigeration load, excepting those cases in which studies show that the savings in refrigeration are insufficient to amortize the added cost of intakes and controls.

2. Location - Locate central units, including built-up and factory-assembled air handling units and self-contained air conditioning units larger than 7½ hp nominal size, outside the space served, preferably in separate rooms in the basement or penthouse. Locate self-contained units not larger than 7½ hp nominal size outside the space where it can be done without undue added cost, but may be installed within the space served.

B. Size and Type of Units - Subject to limitations imposed by zoning requirements and economical duct layout, central units should be as large and few in number as possible. Provide a single air conditioning unit with provisions for space reheat where a single occupancy zone contains more than one exposure zone rather than a number of small single zone units. Provide units with outside air precooling coils (protected by use of preheaters) where outside humidities are high, to reduce the use of reheat at light loads. Units generally should be of the field-assembled type. Factory-built air handling units are to be used only where space restrictions prevent the use of field-assembled units. Factory-built units are not recommended for capacities in excess of 10,000 c.f.m. Self-contained air conditioning units, when used in connection with Paragraph II, B, 2, should not exceed 15 hp nominal size. Self-contained units should have water cooled condensers suitable for use with cooling towers,

excepting that systems of 5 tons capacity or less should have air cooled condensers.

VIII. AIR DISTRIBUTION

A. Ductwork

1. High Velocity - These duct systems have application in existing buildings where space is not available for low velocity ducts, and in new buildings where it can be clearly demonstrated that reduced building construction costs will offset the greater installation and operating costs of the duct systems. High velocity system characteristics are especially suited in providing flexibility in meeting future demands for increased air flows.

2. Duct Arrangement - The arrangement of duct systems will depend largely on the type and location of air outlets required. Economical duct design will usually result if under-window units providing 100% outdoor air and terminal reheat are fed by vertical ducts in outside walls and if ceiling outlets in the interior spaces are fed by horizontal duct systems with vertical main ducts. Architectural and structural features will frequently have a bearing on the final duct arrangement selected. Design duct construction details to provide maximum flexibility to accommodate possible future changes. Provide capped off tee connections in the initial construction where future connections may be made with a minimum of disruption of service.

3. Duct Materials - Ductwork generally should be constructed of aluminum or zinc coated sheet metal. Use corrosion resistant metals and inert material where required to handle wet air or corrosive fumes. Pipe shafts are not suitable for use as ducts because of the difficulty in cleaning and/or decontaminating.

4. Fire Dampers - Install fire dampers in accordance with the requirements of the National Building Code. Fire dampers will be required where ducts pass through fire resistive main vertical duct shafts, interior walls, and partitions of rooms having labeled fire doors (Class C or better) and walls of transformer and elevator machine rooms. Fume hood exhaust systems may require, in addition, a means of sensing inadequate air flow and providing alarm.

5. Air Outlets

   a. Under-window units - Under-window units of either the low pressure or high pressure type are suitable for outside laboratory and office space not over 20 feet in depth. Induction-type units are considered unsuitable for laboratory and animal rooms where limited entry of maintenance personnel is permitted. Further, due to the limited amount (up to 30% average) of outdoor air which the induction-type unit can handle, the overall air conditioning costs are increased by the need for an interior air duct system

to provide the large amounts of ventilation air required in these type spaces.

b. Ceiling Diffusers - Diffusers may be circular, square, rectangular or linear and may have a radial or directional discharge as needed to adequately cover the area served. Combination diffusers and lighting fixtures may be used wherever applicable. Design diffusers to be readily removable for cleaning and to minimize dust streaking. Locate diffusers so that they will not interfere with lights and may be combined with lighting fixtures where necessary. They must be selected so as to avoid downdrafts and be suitably baffled if located close to columns or other obstructions. Special care must be exercised to avoid downdrafts at the face of fume hoods. Do not use the internally aspirating type ceiling diffusers in operating rooms. The perforated panel type, ceiling mounted, is preferable.

c. Wall Outlets - May be used in locations where under-window units or ceiling outlets cannot be used, but must be applied with caution where ceiling heights are low.

d. Return Grilles - In Class A facilities, do not locate return and exhaust transfer grilles in corridor doors or partitions. Corridors are not recommended for use as supply air plenums in cases where clean exhaust air is to be used as makeup air for fume hoods or other ventilating purposes. It is recommended that air suitable for recirculation be collected as closely as possible to the source and ducted to the point of use and supplied via diffusers directly into the space requiring the additional ventilation air. Use an undercut in a door rather than a grille to transfer corridor air into a room which is to be maintained at a slight negative pressure. (A maximum of 50 c.f.m. per door should be used.)

e. Hoods (General) - Provide exhaust hoods over autoclaves, sterilizers, and similar equipment to remove the heat, fumes, and moisture at the source. Take care to insure that adequate makeup air is provided.

f. Chemical Fume Hoods - Design chemical fume hoods for a minimum of 100 feet per minute face velocity (open sash position). Design radiological hoods to provide a minimum of 150 f.p.m. face velocity. A fume hood located in a single module (approximately 200 square feet of floor area) will require upwards of 1200 c.f.m. of ventilation air. In most instances, the makeup air will need to be conditioned and ducted directly into the module from the outdoors. The auxiliary air hood

may be used when it is determined that the conventional hood is impractical from the standpoint of the total air required. Auxiliary air must be delivered to the outside of the hood.

g. Ceiling Plenums - Suspended ceiling spaces are not recommended for use as return air plenums in health related spaces.

IX. REFRIGERATION

A. Refrigerants - Design air conditioning refrigerating plants for the use of Group 1 refrigerants as listed in the American Standard Safety Code for Mechanical Refrigeration.

B. Machine Rooms -

1. If possible, install all portions of a refrigerating plant in a single machine room.

2. Construct machine room enclosures so as to prevent transmission of sound to other parts of the building. The mechanical designer should furnish the architect with all information on noise and vibration from machinery and piping that is required to enable adequate design of floor, wall, and ceiling construction.

C. Types of Equipment -

1. Refrigerating equipment should be electrically driven, diesel driven, or heat actuated of one of the following types:

   a. Motor-driven reciprocating or centrifugal compression equipment.

   b. Turbine-driven centrifugal compression equipment.

   c. Steam or gas-fired absorption equipment.

   d. Diesel-gas engine driven centrifugal compression equipment.

2. Prepare an economic study for each project, showing comparative first costs and operating costs of electrically driven and heat-actuated equipment. Submit each study, together with a recommendation of the systems to be selected, for final approval at or before the final preliminary submission.

3. In the foregoing economic studies, include the following guides:

   a. Assumptions for base electric and gas loads, part and full load operating hours, total tonnage, etc. should be reviewed and agreed upon by the designer and other parties involved.

   b. Estimates of fuel and electric consumption should be prepared.

   c. Fuel and electric costs should be obtained from the latest published rates having Federal Power Commission approval.

   d. Heating value for gas (b.t.u. per cu.ft.) should be in agreement with published values.

   e. Plants being compared should consist of equal numbers of machines of equal size and have identical piping arrangements as far as possible.

   f. Recommended assumptions for boiler efficiencies are as follows:

Oil - 100 hp and under	-	65%
Oil - over 100 hp	-	70%
Gas	-	75%

   g. Do not include in the studies the effect of automatic devices to limit steam and electric consumption unless such devices are to be provided in the project.

   h. Include in installation costs for heat-actuated systems such items as additional support and enclosure requirements for cooling towers, increased condensing-water pipe sizes, additional boiler capacity, increased boiler pressure if required, etc.

   i. Include in installation costs for electric systems such items as additional main feeder, transformer and switchgear costs.

   j. Submit the above required study in summarized form.

4. Where a system is higher in first cost, consider it to be the more economical one only where the excess cost can be amortized by the operating savings in less than 5 years.

D. General Arrangement

The number of refrigerating machines required in any refrigerating plant is the smallest number that will carry the full load and provide sufficient flexibility for light loads. No spare units should be provided. Reserve capacity to handle critical building areas may be included when selecting the combination of machine units to meet the flexibility needs of the system. Where the total load is not over 60 tons, and direct expansion equipment (other than self-contained) is used, either one or two machines may be provided, depending on flexibility requirements. Provide all plants over 60 tons with two water chillers. Furnish justification in cases where a single water chiller only is proposed (over 60 tons).

X. TEMPERATURE AND HUMIDITY CONTROL

A. General

1. Design - In every case, use the simplest system that will serve the purpose.

2. Types of Equipment - Automatic control equipment for ventilating and air conditioning systems may be the electric, electronic, or pneumatic power operated types.

a. Humidity Control and Equipment

Dew point control is generally satisfactory for maintaining desired humidities in systems having surface dehumidifiers. In this case, summer dew point control is most often accomplished by regulating the water flow to the dehumidifier coils. Winter dew point control, where required, may be accomplished by:

(1) Centrifugal atomizer,
(2) Steam spray, or
(3) Pneumatic spray type of industrial humidifiers

using a space humidistat to control the valve supplying steam or water to the humidifier. Individual humidity control is desirable in operating rooms and animal rooms.

B. Room Temperature Control

1. Laboratories - Provide laboratories and ancillary spaces with individual room temperature control. Apply the control to individual reheaters or mixing dampers, depending upon the arrangement of the system.

2. Clinical - Provide all air conditioned laboratories, patient rooms, and other health-related spaces with individual room temperature control.

3. Animal - Provide all animal holding, breeding, and operating rooms with individual room temperature control.

XI. COST ESTIMATES

Cost estimates for air conditioning (excluding electrical power) will vary between 25 and 35 percent of the total costs of construction and fixed equipment, depending on the type of air handling and distribution system selected.

Additional copies of this leaflet may be obtained from:

Office of Architecture and Engineering
Division of Research Facilities and Resources
National Institutes of Health
Bethesda, Maryland 20014